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Alternative Supply Specifications and Estimates of Regional Supply and Demand for Stumpage

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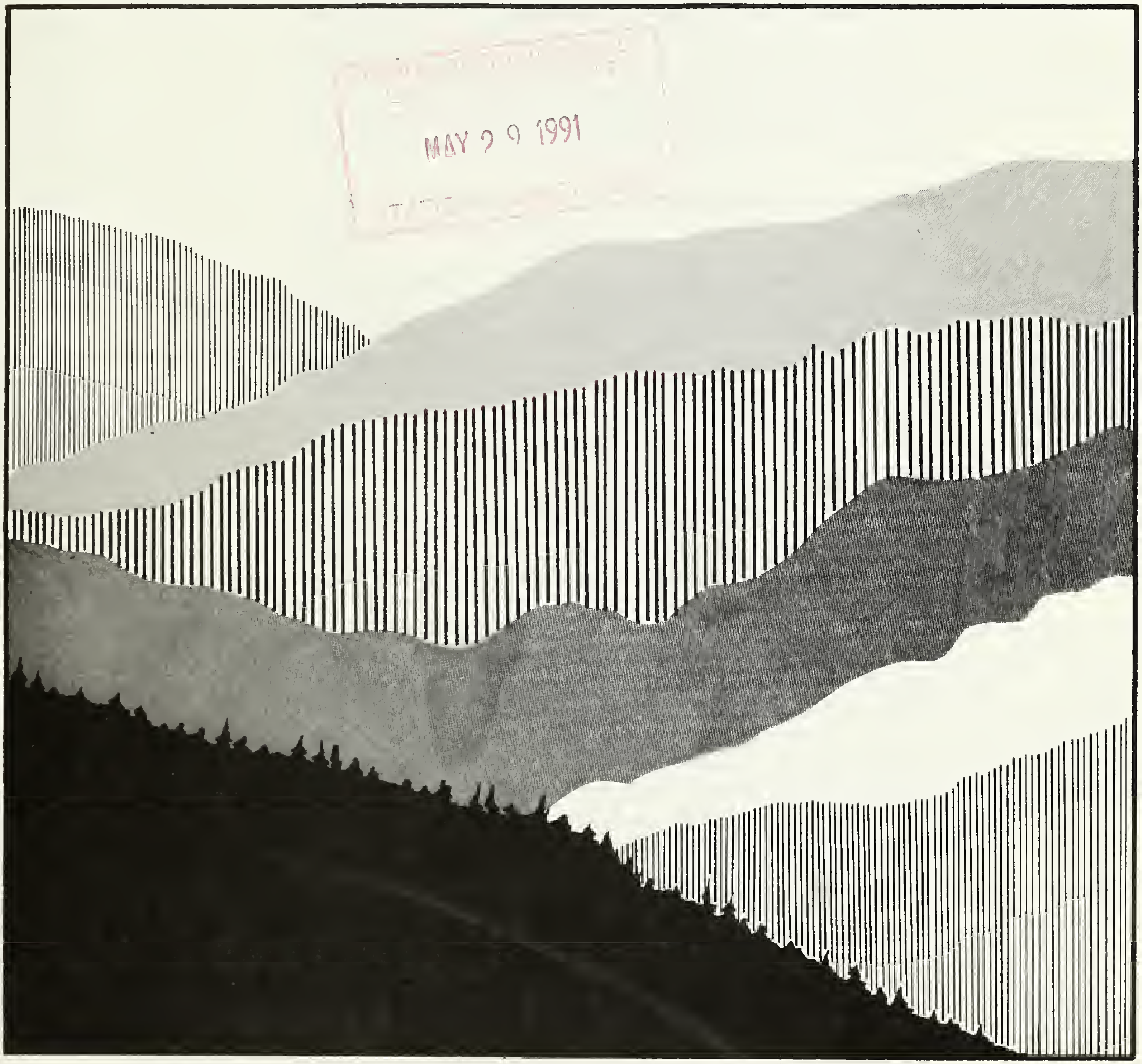

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Abstract

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Four plausible sets of stumpage supply and demand equations were developed and estimated; the demand equation was the same for each set, although the supply equation differed. The supply specifications varied from the model of regional excess demand in which National Forest harvest levels were assumed fixed to a more realistic model in which the harvest on the National Forests depended on current Federal timber sales, uncut-volume-under-contract, and stumpage price. Each set of equations was estimated with annual time-series data for Montana to test the effect of changing supply specification on stumpage demand. Each of the four sets of equations was estimated with two different proxies for the price of stumpage to test the effect of changing the definition of private stumpage price on demand. The slope of the demand curve—the coefficient measuring the change in stumpage price per unit change in quantity demanded—varied, sometimes dramatically, by supply specification and by the proxy used to measure stumpage price.

Keywords: Supply and demand, timber supply, planning, land management planning, forest economics.

Summary

Four sets (models) of supply and demand equations for stumpage were developed. The list of variables affecting demand (the demand specification) was the same for each model and included current period's stumpage price, product prices as meaured by a lumber price index, and conversion costs. The supply specifications differed: They ranged from the model of regional excess demand in which National Forest harvest levels were assumed fixed to a more realistic model in which the harvest on the National Forests depended on current Federal timber sales, uncut-volume-under-contract, and stumpage price. Each set of equations was estimated with annual data for Montana. The models were estimated with two-stage least squares because of correlation between the error term and stumpage price variable. Also, the equations were estimated with two different proxies for stumpage prices to test the effect of the definition of private stumpage price on the estimated coefficients.

The slope of the demand curve—the reciprocal of the coefficient that measured the response in total regional quantity demanded to a change in stumpage price—varied by a factor of two from lowest to highest depending on the specification of supply. Our results also differed depending on the proxy for stumpage price, and analysts are cautioned that the price paid for timber harvested on the National Forests may not be a good measure of the price paid for timber harvested from private lands. For each model, we explained how the estimates of regional supply and demand could be scaled to calculate local-level demand for stumpage.

Contents

Introduction

A simultaneous analysis of supply and demand is usually necessary for quantifying the potential impact of changes in public and private timber programs on stumpage prices and the timber economy. In turn, accurate stumpage prices are needed for preparing and selecting economically efficient management options affecting the timber resource. Public land and resource planners typically formulate and intensively analyze alternatives affecting the supply of forest outputs. The demand for these outputs must also be considered if alternatives are to result in efficient management of natural resources.

The regulations that guide National Forest planning (USDA Forest Service 1982a) indicate how to develop land management alternatives that efficiently produce a mix of desirable uses and outputs. These regulations require that, when possible, demand be analyzed as a price-quantity relation. A key piece of information for alternatives affecting the timber resource, therefore, is the demand for stumpage, which is defined as the slope of the demand curve or, in other words, the rate at which stumpage price can be expected to change because of changes in the quantity of timber demanded.

Several techniques are available to the analyst who must quantify the demand for stumpage at either the multi-Forest (regional) level or the local (National Forest) level (see Adams (1983) for a review). One promising technique is the statistical estimation of demand for stumpage on all ownerships within a timber-producing region. Local or Forest-level demand can then be analytically derived from regional demand. The approach is applicable to any management unit, regardless of agency.

The purposes of this paper were to introduce analysts to several approaches to the statistical estimation of regional supply and demand for stumpage and to alert analysts to potential differences in results. The statistical estimation of regional supply and demand is attractive because of its apparent empirical rigor and its consistency with economic theory—the market interactions that determine price and quantity can be quantified through the simultaneous estimation of separate demand and supply relations. The advantage of the approach is that economic theory can be used to formulate testable hypotheses that consider the effect of National Forest or other public timber programs and factors on stumpage prices in the region. The disadvantage is that results can potentially differ, depending on the variables used to estimate supply and demand. The objective of this research was to investigate the sensitivity of regional demand, particularly the slope of the regional demand curve, to alternative specifications of regional supply and to different definitions of private stumpage prices.

In the next section, we provide a conceptual overview of regional supply and demand estimation, introduce potential difficulties in estimating the theoretical models, and briefly discuss the quantitative adjustment of regional demand estimates to produce local-level demand estimates. (A separate paper (Connaughton and others, in press) provides a detailed discussion of the philosophy and procedures for analytically deriving local-level demand relations from estimates of regional supply and demand.) We then develop four models of the regional supply and demand for stumpage and estimate each model with data from Montana. All models are plausible and can potentially be used in planning. Finally, we provide a summary comparison of the results obtained with each model.

A Conceptual Overview of Demand and Supply Estimation

The first step in estimation was to specify which variables to include in both demand and supply relations. The theoretical specification of the demand equation was relatively straightforward, whereas the specification of supply was more complex. To vary the portrayal of the behavior of timber suppliers, we specified the supply relation in four ways. None of our specifications was clearly superior to the others, theoretically nor empirically; all were plausible.

The next step was to collect the data for the variables in both equations. We developed two proxies for the price of timber harvested on private lands because such prices are not publicly reported. We had little difficulty in collecting the data for the other variables in the demand relation; however, several problems arose as we selected data to describe variables for the supply relation.

Finally, we used special statistical techniques to estimate regional supply and demand because we assumed, based on economic theory, that stumpage prices and quantities were simultaneously determined by the interaction between supply and demand (Kmenta 1971). The special estimation technique, two-stage least squares, gave us estimates that were statistically consistent, though biased; if we had estimated supply and demand with ordinary least squares, the results would have been both inconsistent and biased.

Specification of Demand

The demand for stumpage was derived from the demand for manufactured wood products (Gregory 1972, Haynes 1977). Demand for stumpage measured the relation between the quantity and the price that purchasers would be willing to pay for timber (Connaughton and Haynes 1983). Symbolically, we represented the regional quantity demanded, Q_d, as the function

$$Q_d = f(P_s, P_p, C); \qquad (1)$$

where

P_s = regional stumpage price,
P_p = regional product price, and
C = regional conversion costs.

Economic theory suggested the following hypotheses: (a) quantity demanded is inversely related to stumpage price ($\partial Q_d/\partial P_s<0$), (b) quantity demanded is directly related to the price of manufactured products ($\partial Q_d/\partial P_p>0$), and (c) quantity demanded varies inversely with respect to the (nontimber) costs of conversion ($\partial Q_d/\partial C<0$). Other variables could have been included in the demand relation to represent factors that might influence the behavior of timber purchasers. For example, we might have included variable(s) to describe the capacity of the regional wood products industry to produce manufactured products or the changes in the size of logs that have accompanied the transition from old-growth to managed forests.

Specification of Private Timber Supply

The behavior of industrial and some individual owners of timber is generally believed to be consistent with the theory of the profit-maximizing firm. Adams and Haynes (1980) provide empirical evidence that such a model reasonably simulates historical prices and quantities. Symbolically, we represented the short-run regional private timber supply, Q_s, as the function

$$Q_s = f(P_s, P^*, S_p); \qquad (2)$$

where

P_s = current regional stumpage price,
P^* = future regional stumpage prices, and
S_p = current regional timber inventory.

Economic theory suggested the following hypotheses: (a) quantity supplied is directly related to the current price of stumpage ($\partial Q_s/\partial P_s>0$), (b) quantity supplied in the current period is inversely related to expected future prices ($\partial Q_s/\partial P^*<0$), and (c) quantity supplied is directly related to the size of current inventory ($\partial Q_s/\partial S_p>0$). Other variables might also have been included in equation (2) to represent factors that influenced supply; for example, timber quality, age classes, or species variables might have been represented through a disaggregation of the inventory variable into timber types.

All three hypotheses posed estimation problems because of the data required to represent each variable. The first hypothesis required data on regional average stumpage price for all owners. These data are available for some areas, but no such data existed for stumpage transactions on private land in Montana, our example region. The second hypothesis was impossible to test directly because no observations existed on suppliers' expectations about future prices. Finally, the third hypothesis required that data be available on the stock of timber that was available for harvest; again, the available data fell short of what we needed.

Specification of Public Timber Supply

The relation that describes public timber supply was difficult to specify. Some researchers (for example, Adams 1983, Haynes and others 1981) specify public supply as a fixed (exogenous) quantity that does not respond to market-related variables. The assumption that public supply is exogenous is consistent with the factors that determine the quantity of timber offered for sale (as opposed to the quantity actually harvested) on public land. That is, public budget allocations to forestry, the long lead times between the onset and conclusion of timber-sale planning, and nontimber considerations are among the factors influencing the quantity of timber offered for sale at any time.

The decision to harvest public timber that has been sold, however, is made by private timber purchasers, not the public land management agencies. The quantity that is actually harvested from public lands, therefore, is logically a function of market conditions as well as stand characteristics and contract provisions governing the conditions of a timber sale.

The amount of public timber offered for sale that is actually sold will reflect current and future market conditions. Sold timber may be harvested immediately if contract conditions or accessibility do not preclude operability. The harvest might also be postponed when contract conditions are for a multiyear timber sale; in such cases, the sale becomes part of an uncut-volume-under-contract. The purchaser of National Forest timber who holds a number of timber sales in the uncut-volume-under-contract may choose to harvest most heavily when market conditions are most favorable and to postpone or reduce harvests when market conditions are unfavorable. In the following sections, we develop timber-supply models with a wide range of behavioral explanations for public-timber harvest.

Implementation: How To Choose the Region of Analysis and the Method of Estimation

We chose the region of analysis so that significant flows of timber did not cross its boundaries. This permitted us to estimate one supply and one demand equation. A multiequation, spatial model would have been necessary had significant quantities of timber crossed the region's boundaries.

The choice of a region of analysis both defined some of the data needed to estimate demand and supply and influenced the interpretation of results. Prices, quantities, and other variables that described the timber economy within the region of analysis were regional averages. For example, regional stumpage prices represented the volume-weighted average of prices paid for all species across all sites and ownerships. If the region of analysis had been larger, the results would have been difficult to use for Forest-level analysis. Specifically, the analyst will find it difficult to apply convincingly the results to a Forest with resource characteristics that differ markedly from the regional average.

The method of estimation was influenced by the assumption that stumpage prices and quantities were the result of an equilibrium between supply and demand. Stumpage price and quantity were correlated with the stochastic error term in equations (1) and (2). Ordinary least squares estimates of the equations' coefficients would have been statistically biased (Pindyck and Rubinfeld 1981). An increase in sample size would not have reduced bias, so the coefficients would also have been inconsistent.

To obtain consistent estimates of the coefficients on price in equations (1) and (2), we had to estimate both with two-stage least squares or one of the systems estimation techniques such as three-stage least squares or full-information-maximum-likelihood. Two-stage least squares was used to estimate the results reported in this paper; small sample size (n=19) did not justify the use of the systems estimation techniques. The coefficients were biased, though consistent, when estimated with two-stage least squares.

Problem of Measuring Stumpage Price

Stumpage price is a key variable in both the demand and supply equations. In the demand equation, the estimated coefficient for the stumpage price variable will especially interest analysts because it measures the change in quantity demanded that results from a one-unit change in price. The reciprocal of the coefficient is, therefore, the slope of the regional stumpage demand curve (Haynes and others 1981).

A problem confronting analysts is how to measure stumpage price. Frequently, the only published data on stumpage price are for the public land management agencies. The Forest Service, for example, releases data on the prices paid for timber that is harvested (cut price) and the price of the winning bid for timber that is sold (sold price).

The dilemma is whether or not these data adequately measure stumpage as sold by private timber owners. The contractual arrangements under which public and private timber are sold are different. Public timber has historically been sold under multiyear contracts, whereas private timber is generally perceived as being sold in the spot market (harvest required during a single operating season). Public timber sales may also include environmental or other contractual restrictions that affect the costs of harvesting and that are not typical requirements for harvesting private timber.

The price negotiated for public timber at the time that the timber sale contract is awarded reflects the purchaser's expectations about market conditions that will prevail during the contract period. Private timber prices (particularly for timber harvested on lands owned by the same company that will process the logs) reflect current market conditions more so than Forest Service cut prices because the arrangements for harvesting private timber typically more closely approximate a spot market or a market in which timber must be harvested in the current period. Equivalently, when public timber is harvested, the price paid might only partially (through accounting adjustments in the negotiated price) reflect the current market conditions that influence the price paid for private timber.

How is the analyst to deal with this problem? If data for private timber prices are lacking or not available, the analyst usually has two choices: (a) collect data on a "proxy" variable that is thought to closely depict the desired variable or (b) estimate the specified equations without the desired variable. The consequences for the latter approach are that the coefficients on the variables included in the estimated equations will be biased to the extent that those variables are correlated with the omitted variable (Kmenta 1971). The consequences of the former approach are unpredictable and could, in the extreme, parallel the undesirable results of the analyst's omitting the desired variable.

Our approach was to use two measures of stumpage price as proxies for the actual, unobservable regional average stumpage price paid to all stumpage owners. The first proxy was the cut price or price that purchasers paid for timber harvested on National Forests. The second was a volume-weighted average of the Forest Service cut price and a proxy that measured the maximum average amount that private timber purchasers could pay for stumpage. The latter price was calculated by subtracting the regional average annual logging and manufacturing costs (used in Forest Service appraisals of timber sold) from the value of lumber products (log scale) produced in Montana as reported by the Western Wood Products Association (1962-80).

Analytical Derivation of Local- or Forest-Level Demand From Estimates of Regional Demand and Supply

The relation between the region's average stumpage price and the quantity demanded at the local or National Forest level can be analytically derived from the estimates of regional supply and demand. The procedures are described in Connaughton and others (in press) and have three steps: (a) an analysis of whether adjustment to the local level is appropriate, (b) the analytical derivation of the demand for local stumpage from regional supply and demand, and (c) an evaluation of the reliability of the local-level demand relations.

The derivation procedures are not justified when the local timber economy, including the local characteristics of the timber resource, is different from the regional timber economy. Practical experience is an analyst's best tool in deciding whether the local timber economy is sufficiently similar to the regional economy to justify the derivation procedures. The statistical correlation between local and nonlocal stumpage prices can supplement first-hand knowledge of the local timber economy. These procedures are documented in Connaughton and others (in press).

The derivation procedures define the demand for stumpage at the local level, q_d, as the difference between regional demand, Q_d, and nonlocal supply, Q_{snl}. Symbolically,

$$q_d = Q_d - Q_{snl}; \tag{3}$$

where

q_d = demand for local-level stumpage,
Q_d = regional demand for stumpage, and
Q_{snl} = nonlocal, regional supply for stumpage.

Majerus (1982) and Adams (1983) demonstrate how the approach implied by equation (3) can be used to derive the relation between quantity demanded locally and regional stumpage price. Connaughton and others (in press) develop two additional demand relations: (a) between quantity demanded locally and local stumpage price and (b) between quantity demanded locally and nonlocal stumpage price.

In the sections that follow, we briefly discuss the derivation of Forest-level demand from the regional models estimated for this research. We emphasize that the local-level demand relation discussed here is between <u>regional</u> stumpage price and local quantity demanded, and not between <u>local</u> stumpage price and local quantity demanded. The latter relation can be developed with the procedures of Connaughton and others (in press). Alternatively, a multiequation, spatial equilibrium model would be necessary to capture the effect of harvest changes on local stumpage prices. Theoretically, one would expect the effect on local prices to parallel the effect on regional price if local timber is qualitatively similar to the region's timber and if the costs to transport logs into and out of the local area is a minor part of the total conversion costs. If these conditions are not satisfied, the effects on local prices will not be known.

Four Models of Regional Supply and Demand

We applied the concepts outlined in the previous section to develop four alternative models of regional supply and demand for stumpage and estimated these models with annual data (1962-80) for Montana. The difference between models was the representation of supply in general and public supply in particular. The specification of the demand relation was the same in all four models. Our primary interest was in how the coefficients of the demand equation would change as the specification of supply changed.

We hypothesized that the demand relation had the following form:

$$Q_{dt} = \alpha_0 + \alpha_1 P_{st} + \alpha_2 C_t + \alpha_3 PP_t + \mu_t; \qquad (4)$$

where

Q_{dt} = quantity demanded (harvested, millions of board feet) in year t (t = 1962...1980),
P_{st} = proxy for average, regional stumpage price (dollars per thousand board feet) in year t,
C_t = average regional conversion cost (dollars per thousand board feet, log scale) in year t,
PP_t = index of product prices in year t,
μ_t = stochastic error term with mean equal to zero, constant variance (σ^2), zero auto-correlation, and
$\alpha_0, \alpha_1, \alpha_2, \alpha_3$ = parameters to be estimated.

The hypotheses for equation (4) were: $\alpha_1<0$, $\alpha_2<0$, and $\alpha_3>0$. The coefficient of interest was α_1, which measured the change in quantity demanded per unit of change in price. By examining the differences in α_1 across the four models, the analyst can gain insight into the variation in demand resulting from alternative specifications of supply. None of the supply relations was clearly superior to the others.

The focus on supply was consistent with difficulties that analysts face as they attempt to specify supply in a theoretically sound, empirically realistic manner. Each supply relation was specified, like the demand relation, in linear form. Other authors (for example, Adams 1983) specify demand and supply models that are linear in the logarithms of the variables. The latter type of specification is useful for calculating a single elasticity,[1] whereas the linear specification is useful in harvest scheduling. Neither specification is theoretically superior to the other.

All results were calculated with two-stage least squares and with both proxies for the price of stumpage harvested on private land. A discussion of the sources of the data and the data definitions are in the appendix.

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[1] Elasticity is the percentage change in quantity divided by the percentage change in price. If demand is inelastic, the percentage change in quantity will exceed the percentage change in price; if elastic, the reverse will occur.

Model I: Public Supply Exogenous

In this model, public timber supply was assumed to be exogenous. The demand specification and hypotheses for the demand relation were identical with equation (4).

The symbolic representation of regional supply, Q_{st}, was:

$$Q_{st} = Q_{sft} + Q_{spt};$$

where

Q_{sft} = quantity harvested (thousands of board feet) from public land in year t, and

Q_{spt} = quantity harvested (thousands of board feet) from private land in year t.

Private supply was assumed to be a function of the price of stumpage and the volume of timber on private land. Symbolically,

$$Q_{spt} = \beta_0 + \beta_1 P_{st} + \beta_2 I_{pt} + \mu_{2t}; \tag{5}$$

where

Q_{spt} = annual quantity supplied (harvested, in thousands of board feet) from private land in year t;

P_{st} = stumpage price (dollars per thousand board feet, log scale);

I_{pt} = inventory on private land (millions of cubic feet) in year t;

μ_{2t} = stochastic error term with zero mean, constant variance (σ_2^2), and no auto-correlation; and

$\beta_o, \beta_1, \beta_2$ = parameters to be estimated.

Equations (4) and (5) were estimated with two-stage least squares; the quantity harvested on public land, Q_{sft}, was included as a first-stage instrument in the estimation of both equations because it was assumed to be exogenous. The hypotheses for this model were: $\beta_1>0$ and $\beta_2>0$.

No observations on purchasers' expectations about future stumpage prices were available; bias in the coefficients caused by the omission of this variable was unknown. Current price and inventory may have captured some of the effects of price expectations on quantity supplied and, therefore, served as proxies. Current price, however, would be expected to be an adequate proxy only when prices and economic growth are stable. The coefficient on inventory, β_2, may have incorporated the reservation price of timber (Gregory 1972) or scarcity value because of expectations. High inventories would be associated with low reservation prices or a higher propensity to liquidate the standing inventory.

Annual data on the stock of timber on private land were not available. This data series was, instead, developed by Majerus (1982) from periodic reports of the inventory on private commercial forest land in Montana, assumed growth rates, and reported harvest data.

The results of the estimation of equation (4) with both measures of stumpage price are shown in table 1. All the coefficients in the demand equation were of the expected sign. The coefficients, however, on stumpage price (α_1) were not significantly less than zero ($\alpha = 0.1$).

Table 1—Estimates of demand equation coefficients with 2 proxies for regional average stumpage price for 4 models of the supply of stumpage in Montana[1]

		Variables in the demand equation					
Supply model[2]	Stumpage-price proxy	Constant (α_0)	Stumpage price (α_1)	Conversion costs (α_2)	Product price index (α_3)	$\bar{R}^2$	Durbin-Watson statistic
I	Cut price	1.2×10^6**	-6471.7	-7857.8**	5962.5**	0.45	1.712
		(138575)	(5191.8)	(2501.2)	(2986.0)		
	Volume-weighted	1.1×10^6**	-5511.6	-11117.8**	9127.0**	0.52	1.545
		(186360)	(4145.3)	(4103.7)	(4871.3)		
II	Cut price	1.2×10^6**	-8270.0*	-8259.4**	6604.7**	0.42	1.725
		(140748)	(5136.7)	(2549.1)	(3009.5)		
	Volume-weighted	1.0×10^6**	-7679.7*	-12968.9**	11461.9**	0.48	1.651
		(198177)	(4479.1)	(4380.8)	(5224.1)		
III	Cut price	1.2×10^6**	-4110.4	-7330.4**	4887.8**	0.47	1.650
		(134703)	(4933.3)	(2438.5)	(2883.2)		
	Volume-weighted	1.0×10^6**	-7150.9**	-12517.3**	10982.4**	0.49	1.658
		(178324)	(3829.3)	(3894.8)	(4577.5)		
IV	Cut price	1.2×10^6**	-4156.3	-7340.7**	4906.8**	0.47	1.652
		(134725)	(4934.0)	(2438.9)	(288.6)		
	Volume-weighted	1.0×10^6**	-7879.4**	-13139.3**	11677.0**	0.48	1.648
		(178738)	(3811.1)	(3897.7)	(4571.8)		

* Significant when $\alpha = 0.1$.

** Significant when $\alpha = 0.05$.

[1] Standard errors in parentheses.

[2] Model I is quantity supplied as a function of stumpage price and the inventory on private land; model II is quantity supplied as a function of stumpage price and the inventory on all ownerships; model III is quantity supplied as a function of stumpage price, inventory on private land, and public timber sales in the current year; and model IV is quantity supplied as a function of stumpage price, inventory on private land, public timber sales in the current year, and public uncut-volume-under-contract.

The results of the estimation of equation (5), with both measures of stumpage price, are shown in the first two lines of table 2. Only one of four coefficients had the expected sign, and that one was not significantly greater than zero ($\alpha = 0.1$) as hypothesized.

Table 2—Estimates of supply equation coefficients with 2 proxies for regional average stumpage price for 4 models of the supply of stumpage in Montana[1]

			Variables in the supply equations						
Supply model[2]	Stumpage price proxy	Constant (β_0)	Stumpage price (β_1)	Private inventory (β_2)	Total inventory (β_3)	USDA Forest Service timber sales (β_4)	Uncut-volume-under-contract (β_5)	$\bar{R}^2$	Durbin-Watson statistic
I	Cut price	2.9×10^{6}**	-1993.6	-238.0*				0.26	0.99
		(1.2×10^{6})	(3904.0)	(111.4)					
	Volume-weighted	2.4×10^{6}**	126.1	-190.8*				0.22	0.86
		(9.1×10^{5})	(1743.0)	(87.0)					
II	Cut price	-3.4×10^{6}**	7168.6*		153.11**			0.58	1.575
		(1.2×10^{6})	(4240.7)		(37.7)				
	Volume-weighted	-2.8×10^{6}**	3603.4**		132.8**			0.53	1.570
		(8.4×10^{5})	(1834.5)		(28.0)				
III	Cut price	-2.6×10^{6}*	5780.9*	345.5**		0.203**		0.56	1.837
		(1.3×10^{6})	(3910.4)	(126.9)		(.101)			
	Volume-weighted	-1.9×10^{6}*	2754.9*	278.4**		.233**		0.59	1.934
		(9.3×10^{5})	(1619.6)	(93.0)		(.096)			
IV	Cut price	-2.1×10^{6}*	4673.3	294.7**		.217**	.075	0.57	1.683
		(1.3×10^{6})	(3988.6)	(133.7)		(.101)	(.071)		
	Volume-weighted	-1.7×10^{6}**	2637.6*	242.1**		.247**	.102*	0.63	1.717
		(8.9×10^{5})	(1533.6)	(90.1)		(.092)	(.063)		

* Significant when $\alpha = 0.1$.

** Significant when $\alpha = 0.05$.

[1] Standard errors in parentheses.

[2] Model I is quantity supplied as a function of stumpage price and the inventory on private land; model II is quantity supplied as a function of stumpage price and the inventory on all ownerships; model III is quantity supplied as a function of stumpage price, inventory on private land, and public timber sales in the current year; and model IV is quantity supplied as a function of stumpage price, inventory on private land, public timber sales in the current year, and public uncut-volume-under-contract.

Local-level demand for public timber can be calculated as the difference between the demand for stumpage on all ownerships and the sum of the supply of stumpage from private owners and nonlocal public supply (Connaughton and Haynes 1983). Specifically, local-level demand is calculated as

$$q_d = Q_d - Q_{sp} - \sum Q_{sf}; \qquad (6)$$

where

q_d = local-level demand for public timber,
Q_d = regional demand,
Q_{sp} = private (regional) supply, and
$\sum Q_{sf}$ = sum of nonlocal public supply from different public management units.

Adams (1983) uses this adjustment approach to calculate local-level demand curves from subregional estimates of supply and demand in western Oregon and Washington.

Model II: Total Supply Depends on Price and Inventory

In this model, the quantity of timber supplied from both public and private ownerships was assumed to be a function of stumpage price and timber inventory available for harvest. The model was based on the assumption that the decision to harvest public timber was influenced by the same factors as the decision to harvest private timber.

This specification of public timber supply is, at first glance, partly counterintuitive because the quantity of timber offered for sale by public agencies is generally thought to be a function of many noneconomic, social, and environmental factors, only one of which is the existing timber inventory on public land. The variable that we sought to explain, however, was not the quantity offered for sale, but the quantity harvested. The harvesting decision is made by purchasers of public timber; these purchasers respond to market conditions (including price) as permitted by the conditions of the timber sales contract. The coefficient on total inventory for all ownerships might be a proxy for the reservation price of holding private timber, as it might also have been with model I.

Symbolically, the supply relation for this model was

$$Q_{st} = \beta_0 + \beta_1 P_{st} + \beta_2 I_{st} + \mu_{2t}; \qquad (7)$$

where

Q_{st}	=	annual quantity harvested on all ownerships (in thousands of board feet) in year t,
P_{st}	=	stumpage price (dollars per thousand board feet, log scale),
I_{st}	=	Inventory on all ownerships (millions of cubic feet) in year t,
μ_{2t}	=	stochastic error term, and
$\beta_0, \beta_1, \beta_2$	=	parameters to be estimated.

The hypotheses for this model were $\beta_1>0$ and $\beta_2>0$. Again, annual data were not available for the total stock of timber on all commercial forest land in Montana. The annual time series on stock was developed by Majerus (1982) in the same manner as described for model I.

The results of the estimation of equation (4) are displayed on the third and fourth lines of table 1; results of estimation of equation (7) are displayed in table 2. All the coefficients in both equations had the expected sign, and all were statistically significant ($\alpha = 0.1$). The two different measures of stumpage prices gave estimates of the coefficient on price in the demand equation (α_1) that are within 10 percent of one another; some of the other coefficients varied more widely when the measure of stumpage price was changed.

The adjustment procedure to move from regional demand and supply to local demand followed the general procedure described for equation (3). Nonlocal supply, Q_{snl}, was calculated as the product of the average historical share of total harvest that came from nonlocal sources and regional supply (equation 7). Symbolically, we rewrote equation (3) as

$$q_d = Q_d - m\,Q_s; \qquad (8)$$

where

q_d = local-level demand,
Q_d = regional demand (equation 4),
m = share of total harvest from nonlocal origins,
Q_s = regional supply (equation 7), and
$m\,Q_s$ = Q_{snl}, or nonlocal supply.

Majerus (1982) uses the above technique to calculate the demand for timber on each of the 10 National Forests in Montana. Majerus and others (1988) report a method for calculating the variance of the derived demand equations for individual National Forests. Briefly, the variance of q_d in equation (8) is a function of the variance of regional demand, nonlocal supply, and the covariance between regional demand and nonlocal supply.

Model III: Total Supply Depends on Prices, Private Inventory, and Public Timber Sales

In this model, total harvest was hypothesized to be a function of current period prices, private inventory, and the level of the current period's timber sales on public forest land. In contrast to model II, the level of current-period timber sales on public lands was a major variable that described the public harvest rather than the level of timber inventory on public commercial forest land. Total regional timber supply rather than separate supply specifications for public and private owners was specified to allow for offsetting changes or substitutions between public and private timber.

Symbolically, total regional supply, Q_s, was specified as

$$Q_{st} = \beta_0 + \beta_1 P_{st} + \beta_2 I_{pt} + \beta_4 S_t + \mu_{2t}; \qquad (9)$$

where

Q_{st} = annual quantity supplied (harvested, in thousands of board feet) from all ownerships in year t,
P_{st} = stumpage price (dollars per thousand board feet, log scale) in year t,
I_{pt} = inventory on private land (millions of cubic feet) in year t,
S_t = timber sold (thousands of board feet) on the National Forests in year t,
μ_{2t} = stochastic error term, and
$\beta_0, \beta_1, \beta_2, \beta_4$ = parameters to be estimated.

The hypotheses for this model were: $\beta_1>0$, $\beta_2>0$, $\beta_4>0$. The first two hypotheses were the same as for model I. The third hypothesis was new; β_4 measured the change in total quantity harvested on all ownerships that resulted from a change in the level of the timber sales on public lands. The coefficient β_4 could also be viewed as the propensity to harvest timber given the level of the timber sales program on public lands.

The results of the demand estimation are displayed on the fifth and sixth lines of table 1, and the results of the supply estimation are on the fifth and sixth lines of table 2. All the estimated coefficients had the expected sign. All the coefficients in the demand and supply equations estimated with the volume-weighted-stumpage-price proxy were statistically significant (α = 0.1). All the coefficients in the demand and supply equations that were estimated with the cut-price proxy were also statistically significant except for the coefficient on price in the stumpage-demand equation (α_1).

The adjustment procedure for moving from the regional estimates to local-level demand was similar to model II and followed the general procedure for developing equation (3). Nonlocal supply was defined as the historical share of the region's harvest that originated on nonlocal ownerships. The local demand equation, therefore, was identical to equation (8) with appropriate estimates for model III substituted for the regional demand and supply equations.

Model IV: Total Supply Depends on Prices, Private Inventory, Public Timber Sales, and Public Uncut-Volume-Under-Contract

In this model, uncut-volume-under-contract on public lands was included with other variables to explain total harvest. The other variables were the same as those included in model III: current period price, private inventory, and the current period's timber sales on public lands.

The justification for model IV was that uncut-volume-under-contract represents a backlog or reservoir of timber that purchasers are contractually obligated to harvest; the harvesting decision then depends on current market conditions and opportunities to either harvest private timber or harvest timber from the current period's public timber sales.

Symbolically, model IV was written as:

$$Q_{st} = \beta_0 + \beta_1 P_{st} + \beta_2 I_{pt} + \beta_4 S_t + \beta_5 UVUC_t + \mu_{2t}; \quad (10)$$

where

Q_{st} = annual quantity supplied (harvested, in thousands of board feet) from all ownerships in year t,
P_{st} = stumpage price (dollars per thousand board feet) in year t,
I_{pt} = inventory on private commercial forest land (millions of cubic feet) in year t,
S_t = timber sold (thousands of board feet) on the National Forests in year t,
$UVUC_t$ = uncut-volume-under-contract (thousands of board feet) on the National Forests in year t,
μ_{2t} = stochastic error term, and
$\beta_0, \beta_1, \beta_2, \beta_4, \beta_5$ = parameters to be estimated.

The hypotheses for this model were: $\beta_1>0$, $\beta_2>0$, $\beta_4>0$, and $\beta_5>0$. The first three hypotheses were the same as for model III. The last hypothesis recognized that increases in the uncut-volume-under-contract might encourage contract holders to keep their timber backlogs within manageable limits. At least part of the pressure to increase harvest would likely stem from increases in the number of contracts due to expire within one or two operating seasons. Again, such pressures may have been offset by a reduced incentive to harvest private timber, so supply was specified for all owners combined, and public and private timber supplies were not identified separately.

The results of the demand estimation are displayed on the last two lines in table 1, and the results of the supply estimation are displayed on the last two lines of table 2. All the coefficients had the expected sign. All the coefficients in the demand curve estimated with the volume-weighted-stumpage-price proxy were statistically significant ($\alpha = 0.1$), whereas the coefficient on price (α_1) in the demand equation estimated with the cut price proxy was not statistically significant. Similar results were obtained for the supply relation: all the coefficients were significant ($\alpha = 0.1$) for the relation estimated with the volume-weighted-price proxy, but the coefficients on price (β_1) and the uncut-volume-under-contract (β_5) were not significant in the results obtained with the cut-price proxy. The adjusted coefficient of determination (adjusted R^2) was higher for the supply relation estimated with the volume-weighted-stumpage-price proxy than for any other supply relation.

The procedure for adjusting these estimates of regional supply and demand to the local level were identical to the procedures used for models II and III. Refer to those models for a brief description of the procedure.

Results

The results of this model are currently used in a market simulator that projects the future of the timber economy in Montana (USDA Forest Service 1984) under a variety of assumptions about market conditions, management intensity, and timber availability.

The stumpage price coefficient in the demand equation varied by a factor of two from highest to lowest across all equations. The price elasticity of demand (measured with average regional price and quantity for the period 1962-80) was inelastic regardless of the model or measure of stumpage price (table 3); the elasticities ranged from -0.06 to -0.18. Our results were consistent with those of Haynes and others (1981), who report a price elasticity of demand for the Rocky Mountain Region as -0.044. In general, one would expect the price elasticity of demand to be larger (less negative) for a multi-State region than for an individual State.

Table 3—Comparison of the estimated coefficient on stumpage price and the price elasticity of demand for 4 models of the supply of stumpage in Montana that were computed with 2 regional-stumpage-price proxies

Supply model[1]	Stumpage-price proxy	Coefficient on stumpage price	Price elasticity of demand
I	Cut price	-6471.7	-0.10
	Volume-weighted	-5511.6	-0.13
II	Cut price	-8270.0	-0.13
	Volume-weighted	-7679.7	-0.18
III	Cut price	-4110.4	-0.06
	Volume-weighted	-7150.9	-0.17
IV	Cut price	-4139.2	-0.06
	Volume-weighted	-7168.8	-0.17

[1] Model I is quantity supplied as a function of stumpage price and the inventory on private land; model II is quantity supplied as a function of stumpage price and the inventory on all ownerships; model III is quantity supplied as a function of stumpage price, inventory on private land, and public timber sales in the current year; and model IV is quantity supplied as a function of stumpage price, inventory on private land, public timber sales in the current year, and public uncut-volume-under-contract.

The stumpage price coefficient in the demand equation was statistically significant in only four out of eight equations. According to our conceptual model, stumpage price should have been an important explanatory variable. Our research did not indicate why the stumpage price coefficient lacked significance. The explanation, however, might lie with the proxy for stumpage price. When the Forest Service cut price was used as a proxy for the regional average stumpage price, only one out of four coefficients was significant; when volume-weighted prices were used as a proxy, three out of four coefficients were significant. Similar results were obtained with supply: when Forest Service cut price was used as a proxy, two out of four supply coefficients were statistically significant, and when volume-weighted price was used as a proxy, three out of four were statistically significant. The advantage of using the

Forest Service cut price for estimation is its availability. The disadvantage is that timber sale contract conditions are different between the public and private ownerships; and prices would likely reflect such differences. The volume-weighted-price proxy was an attempt to capture these differences.

Discussion and Conclusions

The variation in coefficients among each of the four sets of supply and demand equations should alert analysts that results will depend on the specification of the conceptual model. Our results also suggested that the standard errors of the estimated coefficients should be carefully interpreted because they measure variation that is contingent on the specification of the estimated model. Because none of the models was clearly superior to the others, the estimation and use of any particular model should depend on the availability of data, preferences of the analyst, purpose of the demand analysis, and degree of realism desired in the analysis.

A final caution to analysts, our results varied according to which proxy we used for stumpage price. In one case, we used the price paid for timber harvested (cut price) on the National Forests in Montana as a proxy for the regional price of stumpage across all ownerships. In another case, as a proxy we used a weighted average of the cut price and a second variable that measured the difference between lumber value (log scale) and regional average conversion costs. The weightings for this second proxy were: (a) the proportion of harvest volume from the public lands and (b) the proportion of harvest volume from private lands in Montana. The equations estimated with the volume-weighted proxy generally had better goodness-of-fit and lower standard errors for the coefficient on stumpage price than the equations estimated with the Forest Service cut-price proxy. As was true for the alternative supply specifications, analysts are cautioned that results will be contingent on the data used to estimate the models.

Our results were indicative of historical demand and supply relations. Typically, analysts must project these relations into the future. A problem separate from estimation then becomes how to project the demand and supply relations through time. At a minimum, separate projections must be made for each of the exogenous variables in the supply and demand equations. Unfortunately, how coefficients will change in the future is not known. For example, will technological improvements make wood substitutes more financially attractive and thereby change the demand coefficient on stumpage price so that it is more negatively sloped? There are no easy answers to this type of question, and the analyst is encouraged to experiment with a variety of scenarios and assumptions about the coefficients and the exogenous variables. The object of such experimention should be to ascertain the vulnerability of a proposed forestry program or investment to unforeseen outcomes and events. If the proposed action is highly vulnerable to an alternative future, caution in decision-making is justified, including an attempt to rethink the problem to reduce vulnerability and increase flexibility for response to unforeseen events.

References

Adams, Darius M. 1983. An approach to estimating demand for National Forest timber. Forest Science. 29(2): 289-300.

Adams, Darius M.; Haynes, Richard W. 1980. The 1980 softwood timber assessment market model: structure, projections, and policy simulations. For. Sci. Monogr. 22. 64 p.

Connaughton, Kent P.; Haynes, Richard W. 1983. An evaluation of three simplified approaches to modeling the regional demand for National Forest stumpage. Forest Science. 29(1): 3-12.

Connaughton, Kent P.; Jackson, David H.; Majerus, Gerard A. [In press]. Deriving local demand for stumpage from estimates of regional supply and demand. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Gregory, G. Robinson. 1972. Forest resource economics. New York: Ronald Press. 548 p.

Haynes, Richard W. 1977. A derived demand approach to estimating the linkage between stumpage and lumber markets. Forest Science. 23: 281-288.

Haynes, Richard W.; Connaughton, Kent P.; Adams, Darius M. 1981. Projections of the demand for National Forest stumpage, by region, 1980-2030. Res. Pap. PNW-282. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 13 p.

Kmenta, Jan. 1971. Elements of econometrics. New York: Macmillan. 655 p.

Majerus, Gerard A. 1982. Econometric estimation of demand and supply curves for timber in Montana, 1962-80. Missoula: University of Montana. 52 p. M.S. thesis.

Majerus, Gerard A.; Jackson, David H.; Connaughton, Kent P. 1988. [In preparation]. Estimating and interpreting the variation in the local demand for stumpage. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Pindyck, Robert S.; Rubinfeld, Daniel L. 1981. Econometric models and economic forecasts. New York: McGraw-Hill. 630 p.

Ruderman, Florence K. 1980. Production, prices, employment, and trade in Northwest forest industries, third quarter 1980. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 47 p.

Ruderman, Florence K. 1981. Production, prices, employment, and trade in Northwest forest industries, third quarter 1981. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 50 p.

U.S. Department of Agriculture, Forest Service. 1982a. National Forest system land and resource management planning. Federal Register. 47(35): 7678-7696.

U.S. Department of Agriculture, Forest Service. 1982b. An analysis of the timber situation in the United States, 1952-2030. For. Resour. Rep. 23. Washington, DC. 499 p.

U.S. Department of Agriculture, Forest Service. 1984. Montana timber demand and supply: a short-run model of the timber market and an assessment of the economy, employment and fuel wood use. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region. 83 p.

Western Wood Products Association. 1962-80. Statistical yearbook of the western lumber industry. Portland, Oregon: Western Wood Products Association. [Published annually].

Appendix

Data Description and Sources: All series annual data, 1962-80.

Variable: Stumpage price **Symbol:** P_s
Units: Dollars per thousand board feet, log scale
Description: Two proxies for regional stumpage price were used: (a) cut price, or the price paid for timber harvested on the National Forests in Montana, and (b) a volume-weighted proxy where public timber price was cut price and private timber price was assumed to equal the difference between the value of wood products produced in Montana and the costs of conversion. Cut price and conversion costs were provided by the USDA Forest Service, Northern Region; the value of wood products (dollars per thousand board feet, converted to log scale with overrun factors provided by USDA Forest Service, Northern Region) reported by the Western Wood Products Association (1962-80).

Variable: Quantity harvested **Symbol:** Q_d or Q_s
Units: Thousands of board feet, log scale
Description: Quantity harvested for all owners and for the National Forests as reported by Ruderman (1980, 1981).

Variable: Conversion costs **Symbol:** C
Units: Dollars per thousand board feet, log scale
Description: Annual logging and hauling cost data developed from timber appraisal data on file with Division of Timber Management, Northern Region, USDA Forest Service; manufacturing cost developed from same sources and converted to log scale with annual overrun figures provided by Division of Timber Management, Northern Region, USDA Forest Service.

Variable: Product price index **Symbol:** PP
Units: Annual index, converted to log scale
Description: Annual lumber and wood products price index for the United States as reported by the U.S. Department of Labor, Bureau of Labor Statistics. Converted to log scale with overrun factors provided by the Division of Timber Management, Northern Region, USDA Forest Service.

Variable: Private inventory **Symbol:** I_p
Units: Millions of cubic feet
Description: Developed for softwood growing stock on commercial forest land in private ownership by Majerus (1982) from periodic survey data reported by the USDA Forest Service (1982b).

Variable: Total inventory in Montana **Symbol:** I_s
Units: Millions of cubic feet
Description: Developed in the same way as private inventory (I_p).

Variable: USDA Forest Service timber sales **Symbol:** S
Units: Thousands of board feet
Description: Volume of timber sold on the National Forests in Montana as reported by the Division of Timber Management, Northern Region, USDA Forest Service.

Variable: Uncut-volume-under-contract **Symbol:** UVUC
Units: Thousands of board feet
Description: Uncut-volume-under-contract at the beginning of the year (end of the previous calendar year) on the National Forests in Montana as reported by the Division of Timber Management, Northern Region, USDA Forest Service.

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Connaughton, Kent P.; Jackson, David H.; Majerus, Gerard A. 1988. Alternative supply specifications and estimates of regional supply and demand for stumpage. Res. Pap. PNW-RP-399. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 19 p.

Four plausible sets of stumpage supply and demand equations were developed and estimated; the demand equation was the same for each set, although the supply equation differed. The supply specifications varied from the model of regional excess demand in which National Forest harvest levels were assumed fixed to a more realistic model in which the harvest on the National Forests depended on current Federal timber sales, uncut-volume-under-contract, and stumpage price. Each set of equations was estimated with annual time-series data for Montana to test the effect of changing supply specification on stumpage demand. Each of the four sets of equations was estimated with two different proxies for the price of stumpage to test the effect of changing the definition of private stumpage price on demand. The slope of the demand curve--the coefficient measuring the change in stumpage price per unit change in quantity demanded--varied, sometimes dramatically, by supply specification and by the proxy used to measure stumpage price.

Keywords: Supply and demand, timber supply, planning, land management planning, forest economics.

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